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SCREENING, COMPETITION AND (DE)CENTRALIZATION

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by

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ABSTRACT

This paper investigates the relationship between the internal and industrial organization of firms. The choice of architecture (Sah and Stiglitz, 1985) entails a spillover effect. Reaction functions in screening rules have a slope which is not positive, i.e. screening levels are strategic substitutes.

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SCREENING, COMPETITION AND (DE)CENTRALIZATION

I. INTRODUCTION

Standard economic analyses of a market are traditionally concerned with the competition between firms. Firms are choosing strategies and taking actions in order to maximize profits and their interactions result in an industry equilibrium. This approach is rather silent about the internal functioning of firms due to the level of aggregation that is adopted. The firm is treated as a black box, which implies that the decision processes and procedures are taken for granted. However, the way in which firms are internally organized might have consequences for their behaviour in the market. Chandler (1990) argues that a perspective relying on markets only in order to understand industrial development is likely to be seriously flawed. He advocates the view that firms and markets evolve together, whereas the former seems more important than the latter in the understanding industrial outcomes.

This paper investigates the relationship between the internal and industrial organization of firms. There are many internal organization choices to be taken. We focus on how different evaluations of the same project are aggregated into an organization decision. Many examples of such choices are around. All members of the security council of the United Nations evaluate each issue and cast their vote. Acceptance of a proposal requires unanimity. Members of parliament vote on many different issues. The adoption of a new law is usually done by majority voting, but constitutional changes require a two third majority. Scientific journals base their acceptance of a paper on reports of referees. The journal has to decide how many referees will evaluate a paper, whether a paper is evaluated simultaneously or sequentially and how their reports are put into a journal decision. A capital budgetting procedure of a firm has to answer which research proposal will be adopted and whether this is done in a decentralized fashion or has to get the approval by many different bureaus. A judicial system has to take some decisions regarding the possibilities of appeal. An accounting firm checking the annual reports of their clients has to decide internally whether a rejection of a report by one of their employees should be checked again or not. University professors don't need the approval of their colleagues in order to start a new research project.

Some aspects of the variety of decision procedures are dealt with in this paper. The internal organization choice is referred to as the choice of architecture (Sah and Stiglitz, 1985) or perceptron (Rubinstein, 1993). An architecture describes how individual or local decisions are aggregated into an organization decision. Many different aggregation rules are possible, but we will limit ourselves to two possibilities. A polyarchy accepts a certain project when there is at least one individual supporting the project. Research projects in universities provide an example. If some member of the scientific community considers a project as promissing, then (s)he carries it out without having to ask somebody for approval. A hierarchy only accepts a project when everybody is favoring it. The above example of the security council provides an illustration.

The performance of the different aggregation rules is analyzed by distinguishing four kinds of decisions: a good (bad) project is either accepted or rejected. Failures are modelled as type-I and type-II errors, where the probability of rejecting good projects is a type-I error and the probability of accepting bad projects is a type-II error. A polyarchy and hierarchy differ with respect to the probability of accepting good and bad projects. A polyarchy accepts a larger percentage of projects than a hierarchy. This is true for good as well as bad projects. Decentralized structures like a polyarchy have therefore a relative advantage in accepting good projects, whereas a centralized structure like a hierarchy is preferred when rejecting bad projects is of primary importance. Aggregation rules (architecture choices) are evaluated by considering their likelihood of failure and success and their associated payoffs.

An architecture usually faces some rivals in a market environment. Universities compete for Ph-D students. Each candidate is screened by several faculty members. The question is whether the architecture choice of a university is influenced by having other universities around. The same question applies to the adoption of projects by firms. However, a distinction has to be made between projects that can be carried out by only one firm and projects which may be adopted by more than one firm. It determines the nature of competition after the approval decision. An example of the first case is the construction of a bridge or the above example of the Ph-D students. The development of a new drug illustrates the second case, because several firms may start independently with it. This second case will be treated in this paper.

The competition between architectures features prominently in this article, whereas Sah and Stiglitz concentrate on a firm in isolation. The industrial organization effects of the internal organization choice are analyzed by considering a model in which two architectures compete against each other. There are zero, one or two firms in the market, which depends on their evaluations of the project. Zero firms are in the market when both architectures reject a project. A firm is a monopolist when it accepts a project and the other firm rejects it. It is assumed that the firms share the market when they both accept a good project. So, a firm accepting a project is either a monopolist or duopolist, depending on the acceptance decision of the rival firm. The loss incurred due to accepting a bad project is assumed to be independent of market structure. These duopoly features reduces the attractiveness of the market on average and is responsible for the result that more firms in the market will favor the acceptance of a hierarchy when the acceptance and rejection probabilities are exogenous (Hendrikse, 1992). Another result is that a hierarchy and polyarchy may coexist in equilibrium.

Architectures do not only have to decide which aggregation rule they are going to use, but they also have to determine with which probability a local screener has to accept or reject projects. Students applying for graduate school face a minimal grade requirement and a minimal expected return on investment plays an important role in the allocation of funds to investment projects in a capital budgetting process. The toughness of screening (i.e. the height of acceptance and rejection probabilities) depends on the benefits associated with type-I and -II errors, the portfolio composition, the choice of architecture and the structure of the market. Acceptance and rejection probabilities are endogenized in this paper. A two stage game theoretic model is developed in order to analyse the screening level choices in a competitive environment. The first stage determines the choice of architecture, whereas the probabilities, by setting reservation screening levels, are chosen in the second stage. This sequence of moves seems natural. Casual empiricism suggests that there are considerable costs involved in changing organizational structure (architecture). These costs are sunk because the old architecture can not be sold to someone else. Architecture decisions are therefore of a long term nature and belong in the first stage. Reservation screening level choices are less difficult or costly to change. They are of a short term nature and are chosen after the choice of architecture has been made.

The profit maximizing architecture and screening level choice is considered first in the monopoly case. It turns out that a polyarchy is chosen when the portfolio is very bad. The reason is that the screening level is set at such a high level that all bad projects are rejected by all bureaus. The relative advantage of a hierarchy in rejecting bad projects is therefore eliminated. Only good projects are accepted and a polyarchy is good at that. The opposite result emerges when the portfolio is attractive. Screening levels are set at a level at which all good projects are accepted. The task for the organization is to reject bad projects and this is done best by a hierarchy. Notice that these architecture choice results with endogenous screening levels are the opposite of the results when screening levels are exogenous.

Reaction functions in screening levels are determined in the duopoly case. They do not have a positive slope and are therefore strategic substitutes in the terminology of Fudenberg and Tirole (1984). A higher screening level of the rival reduces his acceptance probability of good as well bad projects and therefore increases the attractiveness of the market. The profit maximizing response is a lower screening level.

The profit maximizing strategy is determined by the slope of the reaction function and the nature of investment. Strategic substitutes imply that an aggressive action will be met by a passive response by the rival. The nature of investment determines what aggressive behaviour entails. Define the degree of decentralization as the level of investment. An identical screening level at local bureaus in a hierarchy and a polyarchy implies different acceptance probabilities in these architectures and therefore a different market for the other firm. A rival changing from a hierarchy to a polyarchy reduces the attractiveness of the market for the firm. Investment is therefore hard, i.e. a higher level of investment reduces the profits of the rival. Strategic considerations favor a high degree of decentralization, i.e. a polyarchy. Notice that this tendency towards polyarchy holds for a fixed number of competitors in the industry. This strategic effect may be countered by the effect of the number of firms in the industry. It reduces the expected revenue of a firm. A hierarchy is relatively good at dealing with the subsequent increased importance of preventing type-II errors. The same effect is established by choosing a higher screening level.

Another aspect of architecture choice is that it involves a spillover effect. The profit maximizing response of the rival to a change from a hierarchy to a polyarchy of the other firms is a higher screening level, given the screening level at the local bureaus of the other firm. It changes the negatively sloping part of the reaction function from a convex shape to a concave shape. This spillover effect reinforces the choice of a polyarchy from a strategic point of view.

The paper is organized as follows. Section two presents the model. Section three derives and explains the results in the monopoly case. Screening level and architecture choice in a duopoly are treated in section four. Finally, conclusions and avenues for further research are offered.

II. MODEL

A firm is defined as a collection of bureaus. Each bureau evaluates projects and decides to either accept (A) or reject (R) a project. The pool of projects faced by a bureau consists of good and bad projects. A good project generates a positive payoff, whereas a bad project has a negative return. It is assumed that there are errors of judgment involved in deciding which project to adopt. This is modelled by incorporating a probability that a bad project is accepted and a probability that a good project is rejected.

It is assumed that every individual (bureau) is evaluating/sampling the same projects and that this is done independently. Suppose that a bureau is accepting a project with probability p and that a firm consists of two bureaus. Figure 1 represents this situation.

The incidence of type errors made by an organization is influenced by the way in which individual decisions are aggregated into an organization decision. Sah and Stiglitz (1985) have modelled this by defining a hierarchy as an organization which only accepts a project when there is unanimity between all bureaus, whereas a polyarchy only rejects a project when every bureau rejects it. A polyarchy will accept a particular project with probability p(2-p), whereas this probability is p^2 for a hierarchy.

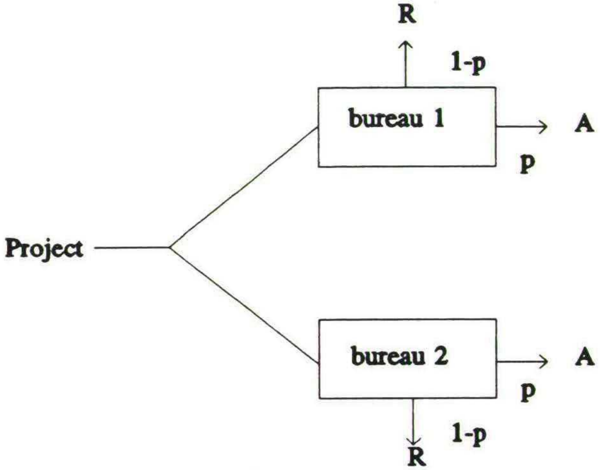


Figure 1: Firm as a collection of bureaus

The composition of the portfolio of projects is characterized by α, which is defined as the proportion of good projects in the pool of available projects. A particular project is therefore good or bad, which has to be reflected in the probability p. This probability is a conditional probability and we define therefore more specifically $p(A \mid B)$ as the probability that a bad project is accepted and $p(A \mid G)$ as the probability that a good project is accepted. The acceptance probability of a firm depends on five aspects. They are the nature of the project, the composition of the portfolio, the acceptance probability of a particular bureau, the number of bureaus and the architecture choice of the firm. The acceptance probability of a bad project by a hierarchy with two bureaus is $(1-\alpha)p(A \mid B)^2$. Similarly, a polyarchy with two bureaus accepts a good project with probability $\alpha p(A \mid G)(2-p(A \mid G)$.

It is sufficient for our purposes to deal with the probabilities of accepting good and bad projects for the architecture as a whole. Define f_H(,f_P) as the probability that a hierarchy (,polyarchy) is accepting a good project and g_H(,g_P) as the probability that a hierarchy (,polyarchy) is accepting a bad project. A polyarchy with two bureaus has therefore $f_p = p(A \mid G)(2-p(A \mid G))$.

It follows immediately from the definitions of a hierarchy and a polyarchy that

$$f_H < f_P$$

and

$$g_H < g_P \, ,$$

i.e. a polyarchy accepts a larger proportion of good as well as bad projects compared to a hierarchy.

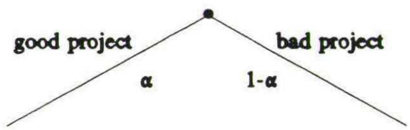
It is assumed that there is some filtering, i.e. the probability that a bad project is judged to be good is smaller than the probability that a good project is accepted ($p(A \mid B) < p(A \mid G)$). This implies that

$$g_H < f_H$$

and

$$g_P < f_P .$$

The present value of costs associated with accepting a bad project are defined to be W, whereas a good project generates a payoff of V. The duopoly case involves two values of accepting a good project. It depends on the decision of the rival whether the market has to be shared or not. We assume that the gains associated with a good project are split equally when both architectures accept the project. The loss associated with accepting a bad project is assumed to be independent of market structure. Figure 2 summarizes these assumptions.



	A	R
A	(V/2,V/2)	(V,0)
R	(0,2)	(0,0)

	A	R
A	(-W,-W)	(-W,0)
R	(0,-W)	(0,0)

Figure 2: Acceptance decisions and duopoly payoffs

The expected profits of a monopolist having architecture i are

$$Y_i = \alpha f_i V - (1-\alpha)g_i W.$$

The expected profits of a firm having architecture i and facing a competitor with architecture j are Y_{ij}. We have therefore

$$\begin{aligned} Y_{ij} &= \alpha f_i\,(f_j V/2 + (1-f_j)V) - (1-\alpha)g_i W \\ &= \alpha f_i(1-f_j/2)V - (1-\alpha)g_i W. \end{aligned}$$

We have assumed that the probability of acceptance is f_i and the probability of rejection is g_i. These probabilities are the aggregation of probabilities of lower bureaus accepting projects. The probability of a lower bureau accepting a project was taken independent of the architecture. One way of endogenizing this probability is to assume that each project evaluator uses a reservation screening level S^i (Sah and Stiglitz, 1986). If the observed profit is above the reservation level then the project is accepted, and it is rejected otherwise. Suppose that the project evaluator observes

$$y = x + \Theta,$$

where x is the benefit of the project and Θ is distributed independently of x. The distribution function of Θ is denoted by $M(\Theta)$ and its density by $m(\Theta)$. The screening function, then,is given by

$$p(x,S) \equiv \text{Prob}\{y \geq S\} = 1 - M(S-x).$$

Changing S has two effects. "Increasing S increases the probability of a good project being rejected (Type-I error) and decreases the probability of a bad project being accepted (Type-II error). The reservation price is chosen to balance off these errors" (Sah and Stiglitz, 1986, p 722).

We will assume that the portfolio of projects consists of only two types. The return on a good project is V, whereas a bad project yields -W. It is also assumed for reasons of tractability that there are only two bureaus in an architecture. We have therefore

$$f_H(V,S^H) = (p(V,S^H))^2$$

$$g_H(-W,S^H) = (p(-W,S^H))^2$$

$$f_P(V,S^P) = p(V,S^P)(2-p(V,S^P))$$

$$g_P(-W,S^P) = p(-W,S^P)(2-p(-W,S^P)).$$

Firms have to make two choices. They determine first their architecture choice simultaneously and independently. The profit maximizing screening levels are chosen simultaneously and independently after the architecture choice has been made. This two stage game is solved for its subgame perfect Nash equilibrium.

III. Monopoly

The determination of the architecture choice is difficult without a specification of the distribution of θ because the reservation screening levels are set differently in the different systems. We consider therefore the case where the proportion of good projects in the initial portfolio is less than one-half (, i.e. $0<\alpha<.5$), the distribution of errors is uniform with support $[-\Psi,\Psi]$ and $0 < V,W < \Psi$. Technicalities regarding the derivation of the profit maximizing screening level choice can be found in the appendix. The flavor of our results is described by focussing on boundary solutions for the profit maximizing screening level choice. Figure 3 summarizes the profit maximizing screening level and architecture choice of a monopolist. (Boundary as well as interior solutions are derived in the appendix. They are summarized in figure 6.)

α	S^i	Architecture choice
$\alpha < \alpha_H$	$S^P = \Psi - W$ $S^H = \Psi - W$	P
$\alpha_H \leq \alpha < \alpha_P$	$S^P = \Psi - W$ $S^H = -\Psi + V$	$P > H$ $\Leftrightarrow \alpha V < (1-\alpha)W$
$\alpha_P \leq \alpha$	$S^P = -\Psi + V$ $S^H = -\Psi + V$	H

Figure 3: Profit maximizing screening level and architecture choice.

There are a number of conclusions to be drawn from figure 3. First, screening levels don't increase when the portfolio improves. This is obvious because an improved portfolio increases the probability of a good project being rejected. The appropriate response is therefore to set the screening level at a lower level, or at least not to increase it.

Second, a polyarchy is chosen when the portfolio is bad. This seems to be counterintuitive, given the results with exogenous screening levels. However, the profit maximizing screening level is set at such a high level that the probability of accepting a bad project is reduced to zero. A firm is therefore accepting only good projects. If somebody knows that the project is good with probability one because $y > \Psi - W$, then the organization should accept it. A polyarchy is doing that.

Third, an organization chooses a hierarchy when the portfolio is relatively good. The screening levels are chosen low enough such that all good projects are accepted. The probability of accepting a bad project has to be minimized and this is done by a hierarchy. If one of the bureaus knows for sure that the project is bad because $y < -\Psi + V$, then this bureau should have veto power in rejecting the project. A hierarchy implements this feature.

Fourth, we saw in the previous section that a hierarchy rejects more good projects than a polyarchy when screening levels are exogenous. A hierarchy will respond to this disadvantage by setting a lower screening level than a polyarchy for intermediate levels of the portfolio composition when the reservation screening level choice is endogenous.

Finally, a polyarchy will be chosen for intermediate levels of the portfolio composition if and only if $\alpha V - (1-\alpha)W$ is negative. An increase in V increases the range of values of W for which a hierarchy is chosen. The explanation for this is that the reservation screening level of a hierarchy is increasing, whereas the screening level of a polyarchy doesn't change. The performance of a hierarchy is improved with respect to the rejection of bad projects, whereas a polyarchy maintains the same probability of rejecting bad projects. An increase in W might result in a switch from a hierarchy to a polyarchy. The reservation screening level of a polyarchy is adjusted downward, whereas S^H doesn't change. This implies that a polyarchy improves its performance with respect to the acceptance of good projects, whereas a hierarchy does not. The comparative statics regarding a change in the portfolio composition is similar to the change in V. Figure 4 summarizes the comparative statics results regarding the architecture choice of a monopolist for the situation with exogenous screening rules (Hendrikse, 1992) and endogenous screening rules. The parameter k in the graphs of the exogenous screening rule case depends on p(A | G) and p(A | B). The case k > 1, which holds when p(A | G) < .5, is reflected in figure 4.

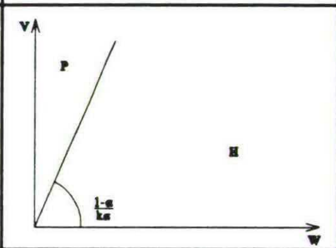
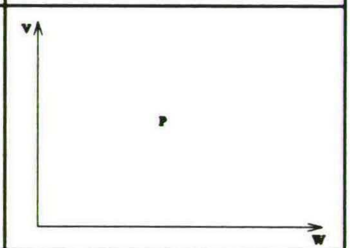
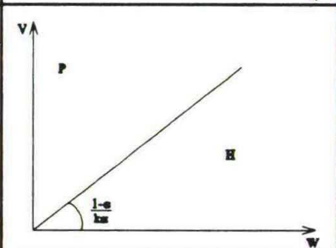
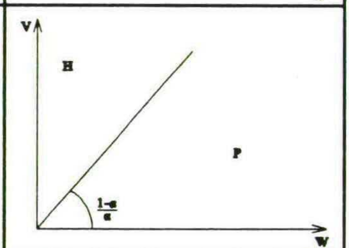
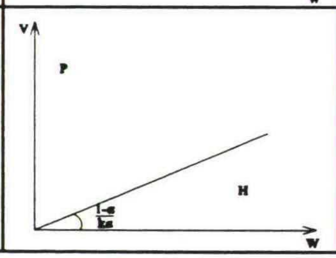
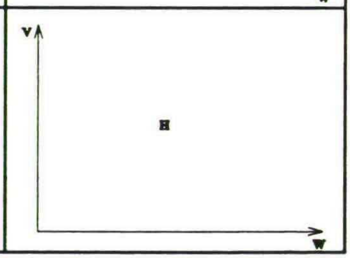
Screening rule / Portfolio composition	exogenous	endogenous
$\alpha \in [0,\alpha_H)$		
$\alpha \in [\alpha_H,\alpha_P)$		
$\alpha \in [\alpha_P,1)$		

Figure 4: Portfolio composition and architecture choice

IV. Duopoly

The screening level choice of rival j affects the expected profits of architecture i, because it determines the probability of having a monopoly or duopoly. Having a potential rival firm in the market reduces the expected value of winning. These expected profits are

$$\alpha f_i(1-f_j/2)V - (1 - \alpha)g_i W.$$

The strategic interdependence between the profit maximizing screening level choices follows immediately from the above equation. The profit maximizing screening level choice S^i depends on S^j, because S^j determines f_j. The comparative statics analysis in the monopoly situation indicated that a worsening of the portfolio results in a screening level choice which is non decreasing. A less attractive portfolio might be due to a higher probability of having a rival in the market. This occurs when the screening level of the other firm decreases. We have therefore a negative relationship between the screening level choices. The reaction or best response functions have a negative slope, where the reaction function of architecture i is defined as the profit maximizing response of S^i on S^j. Screening levels are strategic substitutes in the terminology of Fudenberg and Tirole (1984).

A second implication is that the choice of architecture involves a spillover effect. The profit maximizing screening level choice of architecture i is influenced by the value of f_j. The value of f_j depends on the choice of architecture, given the level of S^j. If firm j adopts a polyarchy, then $f_P(V,S^P) = p(V,S^P)(2-p(V,S^P))$. The probability $p(V,S^P)$ is equal to 0 when $S^P = \Psi - W$ and increases to 1 when S^P decreases to $-\Psi + V$. The decrease in S^P increases $f_P(V,S^P)$ at a decreasing rate, i.e. changes in S^P will have a smaller impact on the reservation screening level choice of firm i when the value of S^P is lower. The slope of the reaction function of a firm facing a polyarchy is therefore finite when the rival has a screening level for its local bureaus just below $\Psi - W$, whereas the reaction function is vertical when the screening level choice of the rival is equal to $-\Psi + V$. The reverse holds when firm j has a hierarchy, because $f_H(V,S^H) = p(V,S^H)^2$. Changes in S^H have a small impact on the profit maximizing screening level of firm i when S^H is close to $\Psi - W$, whereas it has a large impact when it is approaching $-\Psi + V$. The slope of the reaction function of a firm facing a hierarchy is therefore finite when the rival has a screening level for its local bureaus just above $-\Psi + V$, whereas the reaction function is vertical when the screening level choice of the rival is equal to $\Psi - W$. Notice that $f_P(V,\Psi-W) = f_H(V,\Psi-W) = 0$ and $f_P(V,-\Psi+V) = f_H(V,-\Psi+V) = 1$. We have therefore that the profit maximizing screening level of architecture i when faced with architecture j is higher (not lower) for j = P than j = H when the level of S^j is fixed. This means in terms of reaction functions that R^{iP} is located to the right of R^{iH}, i.e. architecture i will choose a higher screening level for its local bureaus when faced with a polyarchy than when the rival has adopted a hierarchy. R^{ij} is defined as the reaction function of architecture i facing architecture j. A rival switching to a polyarchy renders the market less attractive, which implies that the profit maximizing response is not to decrease the reservation screening level.

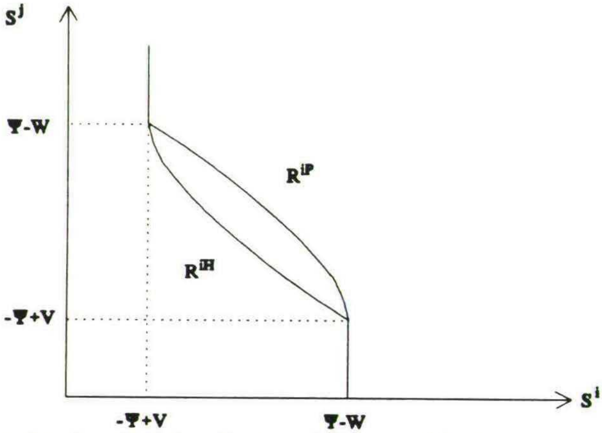


Figure 5: Reaction function of architecture i facing architecture j

Figure 5 depicts the strategic substitute and the spillover features of the profit maximizing screening level choice. It also illustrates that R^{HP} and R^{PP} have the same shape. The previous section has shown that a hierarchy will never choose a higher screening level than a polyarchy in order to compensate for its relative high incidence of type-I errors. R^{HP} is therefore located to the left of R^{PP}. Similarly, R^{HH} is located to the left of R^{PH} and they have the same curvature.

One standard property of reaction functions with strategic substitutes seems to be violated in figure 5. The profits of firm i decrease when the level of S^j decreases. However, screening levels apply to local bureaus in an architecture, whereas the relevant strategic variable for a firm is the acceptance probability of a rival firm. If we transform the screening level choice of bureaus in firm i and j into acceptance probabilities of good projects and use these probabilities as strategic variables, then we retain the property that profits on the reaction function of a firm increase when the level of the strategic variable of the rival firm is lower.

The curvature of the reaction function implies that there are three pure strategy Nash equilibria in screening levels when both firms adopt the same architecture. One equilibrium consists of firm 1 choosing screening level Ψ-W for its local bureaus and firm 2 choosing -Ψ+V. The second equilibrium reverses these screening level choices. Finally, there is a symmetric Nash equilibrium in which both firms choose the same screening level. The slopes of the reaction functions in the neighborhood of this equilibrium are such that this equilibrium is unstable. The explicit expression for the symmetric Nash equilibrium screening level choice can be obtained by using the formula of Cardano for equations of degree three. The solution is cumbersome and will not be presented. The comparative statics analysis with respect to the parameters, α, V, W and Ψ shows that the equilibrium screening level choice will decrease when either α increases or V increases, i.e. screening will be less tough when the expected gain of choosing a project goes up. The same result emerged in the monopoly situation. Figure 9 in the appendix illustrates these results for the duopoly situation. Finally, there are two pure, asymmetric Nash equilibria when the two firms adopt different architectures. Figure 6 shows the equilibria for the different choices of architecture.

<table>
<tr><th>Architecture choice</th><th>Figure</th></tr>
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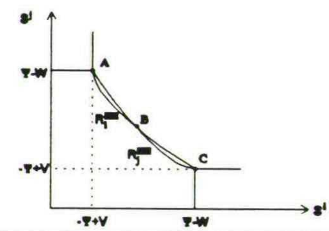
j=H</td><td>
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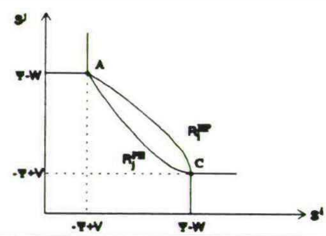
j=P</td><td>
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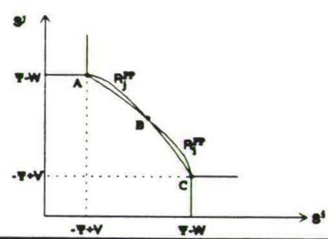
j=P</td><td>
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Figure 6: Equilibrium screening rules, given the choice of architecture

If the strategic situation is such that one of the firms is allowed to choose its screening level first, then it will try to structure the market to its own advantage by the choice of its architecture. The strategic aspects of the screening level choice are analysed by using the strategy typology of Fudenberg and Tirole (1984). There is one incumbent firm and a rival considering entry into the industry. The profit maximizing business strategy of the incumbent depends on the nature of competition (strategic substitutes or strategic complements), the nature of investment (hard or soft) and the entry decision of the rival firm. An implication of a market with strategic substitutes is that an aggressive (passive) decision by the incumbent will be followed by a passive (aggressive) choice of the follower. The profit maximizing strategy for the leader in this situation is to behave always aggressive, regardless the entry decision of the rival.

The strategy typology requires a definition of investment and the determination of its nature. The investment decision is the choice of architecture. (Notice that investment is a discrete variable because it is either a polyarchy or a hierarchy.) Investment is defined as the amount of decentralization. A switch from a hierarchy to a polyarchy is an increase in the level of investment (decentralization). Another way of interpreting this decision is to view architecture choice as an investment in the probability of accepting a project. Investment is defined as hard (soft) when an increase in the level of investment decreases (increases) the profits of the rival firm. Decentralization is a hard investment because a switch to a polyarchy increases the probability of accepting a project. This results in a less attractive market for the rival. The second important aspect of investment in the determination of the strategic architecture choice is the spillover effect. Investment in decentralization implies a negative spillover effect. (The adoption of a polyarchy increases the acceptance probability of a project by the incumbent and therefore reduces the attractiveness of the market for the rival.)

The entry decision of the rival is the final ingredient in the strategic over- or underinvestment decision by the incumbent. It has been shown that investment in decentralization is a hard investment, screening levels are strategic substitutes (i.e. reaction function has a negative slope) and there is a negative spillover effect. This implies that the incumbent will overinvest in decentralization, regardless the entry decision of the rival. An aggressive decision (overinvestment in decentralization) by the incumbent structures the market in such a way that the profit maximizing response of the rival will be passive or there will be no entry at all. This strategy is called the Top Dog strategy. The negative spillover effect only reinforces the overinvestment decision. The strategic choice of a polyarchy by the incumbent reduces the amount of type-I errors and the intensity of rivalry. However, the number of type-II errors will increase, which is responded to by a higher screening level.

Figure 6 seems to be at odds with this result when it is assumed that the multiplicitly of equilibria is resolved by having the incumbent choose a screening level first. Point A is, due to boundary effects, always most attractive to incumbent i. The profit maximizing screening level of the incumbent is so low that it accepts all good projects. It is important to prevent type-II errors, which is achieved by choosing a hierarchy. The choice of architecture by the incumbent will therefore not have any effect on the profits of the entrant. There is a difference regarding the acceptance of bad projects at $-\psi + V$ between the two architecture choices of the incumbent. However, this does not influence the payoffs of the entrant, i.e. f_i, not g_i, determines the payoffs of entrant j. The profit maximizing screening level response of the entrant to $-\psi + V$ is $\psi - W$, which results in the rejection of all bad projects. Entrant j has to minimize type-I errors in its choice of a profit maximizing architecture. This is done by a polyarchy.

Notice that the approach adopted in this paper is not in line with the famous observation by Chandler (1962) that 'Structure follows Strategy'. Structure (architecture) is the long run decision variable of the model and is therefore put in the first stage of the game, whereas the screening level has a short run flavour and emerges in the second stage of the game. This sequencing of decisions seems to imply that strategy follows structure. However, this is not correct. These observations are trying to formulate an answer to an ill formulated question. The solution method of backward induction implies that the first period will set the stage for and induce certain behavior in the second stage, but the second period will also cast its shadow backward to the first period. Architecture and screening level choice are determined jointly.

V. CONCLUSIONS AND FURTHER RESEARCH

We have shown that the choice of architecture is determined by the number of competitors, decision theoretic as well as strategic considerations. Decision theoretic aspects were reflected by the probabilities of accepting and rejecting projects. The costs and benefits associated with bad and good projects determined the profit maximizing architecture choice. The number of competitors influenced this choice because the benefits of accepting a good project were reduced in the duopoly situation. This favored the adoption of a hierarchy. Strategic considerations may also have an effect on the aggregation rule adopted by the incumbent firm because it structures the expected payoffs of a potential entrant. Screening rules turned out to be strategic substitutes. A polyarchy is usually favored from a strategic point of view.

There are several other interesting issues to be addressed in this environment. Examples are the optimal number of decision units in an architecture (, represented in f_H, g_H, f_P and g_P) and the optimal degree of consensus (Sah and Stiglitz, 1988). Third, the performance of the different architectures might be enhanced by taking into account the information generated by the decision of the lower bureau. Evaluators can update their prior information from observing other evaluators' acceptance or rejection decision. A rejection in a polyarchy or an acceptance in a hierarchy changes the screening level choice of the higher bureau (Meyer, 1991). Fourth, the quality of the remaining pool of projects (α) changes when a project is evaluated. Fifth, the result of more competition resulting in more centralized decision structures depends on the assumption that the investment costs associated with a bad project in a duopoly are of the same magnitude as those in a monopoly. A richer model might make these costs dependent on market structure (Loury, 1979). Sixth, capacity limits regarding the number of projects that can be executed influences the intensity of rivalry in the market. Finally, a topic not dealt with in this paper are incentive considerations (Seber and Wu, 1992).

APPENDIX

We will derive the profit maximizing architecture and screening level choice of a monopolist. The duopoly situation in terms of reaction functions will be treated subsequently. The analysis proceeds like in the classical theory of statistical inference. A decision function will be derived which tells us what action to take based on the sample data. (A decision function is chosen which, in some way, keeps type I and II errors as small as possible.) It is constructed to minimize Bayes risk, i.e. the expected value of the risk function. The risk function is the expected loss associated with a parametervalue characterizing the unknown distribution. The decision function is in our model the profit maximizing reservation screening level and the sample data consists of the outcome of the evaluation of a project by a bureau. Bayes risk can be calculated because the distribution of projects and the exact value of all the losses (V and W) is known.

Define x as the net benefit of a project. We assume that

$$x = \begin{cases} V & , \alpha \\ -W & , 1-\alpha \end{cases}$$

where $V,W \in (0,\Psi)$ and $\alpha < .5$. The probability that a project with benefit x will be accepted is

$$p(x,S^i) \equiv \text{Prob}\{y \geq S^i\} = \text{Prob}\{x + \Theta \geq S^i\} = 1 - M(S^i\text{-}x)$$

where $\Theta \in U(-\Psi,\Psi)$, i.e. Θ has an uniform distribution with support $[-\Psi,\Psi]$.

We will face several intervals in determining the profit maximizing screening level. It is therefore convenient to define the indicator function

$$I_{(a,b)}(c) = \begin{cases} 1 & , c \in (a,b) \\ 0 & , \text{otherwise.} \end{cases}$$

The probability of accepting a project can now be written as

$$\begin{aligned} p(x,S^i) &= I_{(-\infty,-\Psi)}(S^i-x) + (1 - M(S^i-x))\, I_{[-\Psi,\Psi]}(S^i-x) \\ &= I_{(-\infty,-\Psi)}(S^i-x) + \left(1-\frac{S^i-x+\Psi}{2\Psi}\right) I_{[-\Psi,\Psi]}(S^i-x) \\ &= I_{(-\infty,-\Psi)}(S^i-x) + \frac{\Psi+x-S^i}{2\Psi}\, I_{[-\Psi,\Psi]}(S^i-x) \end{aligned}$$

and the derivative of this probability with respect to the reservation screening level S^i as

$$\begin{aligned} p_{S^i}(x,S^i) &= -m(S^i-x) \\ &= \frac{-1}{2\Psi}\, I_{[-\Psi,\Psi]}(S^i-x). \end{aligned}$$

The contribution of the two local bureaus determines the expected profits of architecture i. The expected profits of architecture i are $\alpha f_i V - (1-\alpha) g_i W$. Each bureau in a firm is choosing its profit maximizing reservation screening level independently of the other bureau. The first order condition with respect to the expected profit maximizing screening level in a symmetric Nash equilibrium for a polyarchy is

$$E\{x(2-p(x,S^P))p_{S^P}(x,S^P)\} = 0$$

$$\Leftrightarrow\ -\ E\{x(3\Psi+S^P-x)I_{[-\Psi,\Psi]}(S^P-x)\}/4\Psi^2 = 0$$

$$\Leftrightarrow\ \alpha V(3\Psi+S^P-V)I_{[-\Psi,\Psi]}(S^P-V)-(1-\alpha)W(3\Psi+S^P+W)I_{[-\Psi,\Psi]}(S^P+W) = 0$$

$$\Leftrightarrow\ S^P = -3\Psi + \frac{\alpha V^2 I_{[-\Psi,\Psi]}(S^P-V)+(1-\alpha)W^2 I_{[-\Psi,\Psi]}(S^P+W)}{\alpha V I_{[-\Psi,\Psi]}(S^P-V)-(1-\alpha)W I_{[-\Psi,\Psi]}(S^P+W)}.$$

Notice that S^P is inversely related to α. An improved portfolio decreases the profit maximizing reservation screening level. The first order condition for a hierarchy is

$$E\{xp(x,S^{H})p_{S^{H}}(x,S^{H})\} = 0$$

$$\Leftrightarrow S^{H} = \Psi + \frac{\alpha V^{2} I_{[-\Psi,\Psi]}(S^{H}-V)+(1-\alpha)W^{2}{}_{[-\Psi,\Psi]}I(S^{H}+W)}{\alpha V I_{[-\Psi,\Psi]}(S^{H}-V)-(1-\alpha)W I_{[-\Psi,\Psi]}(S^{H}+W).}$$

The indicator functions in the expressions of the profit maximizing reservation screening levels delineate five intervals. If $S^{i} \leq -\Psi - W$, then every project will be accepted and the probability of accepting a project is therefore one. The expected profits are the same for both architectures and equal to $\alpha V-(1-\alpha)W$.

Suppose that $-\Psi-W < S^{i} \leq -\Psi + V$. Both expressions yield a solution which does not fall within this interval. We have therefore a boundary solution. Both architectures maximize their expected profits by choosing their reservation screening level equal to $-\Psi + V$. This is obvious because any realization of y smaller than $-\Psi + V$ reveals that the project is bad. Expected profit maximization requires that the reservation screening level should be at least $-\Psi + V$. The expected profits of a polyarchy are

$$\alpha V - (1-\alpha)W(2\Psi-V-W)(2\Psi+V+W)/4\Psi^{2} \tag{1}$$

and those of a hierarchy are

$$\alpha V - (1-\alpha)W(2\Psi-V-W)^{2}/4\Psi^{2}. \tag{2}$$

It is obvious that the profits of a polyarchy are smaller than those of a hierarchy. Every good project will be accepted by both architectures for this reservation screening level. The performance of an architecture depends therefore only on how good they are at rejecting bad projects. A hierarchy is best at doing that.

Suppose that $-\Psi + V < S^i < \Psi - W$. Define

$$k(\alpha,V,W) \equiv \frac{\alpha V^2 + (1-\alpha)W^2}{\alpha V - (1-\alpha)W}.$$

The function $k(\alpha,V,W)$ is decreasing in α. The expression of the profit maximizing reservation screening level of a polyarchy is

$$S^P = -3\Psi + k(\alpha,V,W).$$

This is an interior solution when

$$2\Psi + V < k(\alpha,V,W) < 4\Psi - W.$$

The interior solution is a decreasing function of α, i.e. an improvement in the composition of the portfolio will lower the profit maximizing screening level of local bureaus in a polyarchy.
The boundary solution Ψ - W generates expected profits of

$$\alpha V(V+W)(4\Psi - V - W)/4\Psi^2. \tag{3}$$

This boundary solution will emerge when there is not an interior solution and

$$(1) \leq (3)$$

$$\Leftrightarrow \alpha \leq (2\Psi - V - W)W(2\Psi + V + W)/(V+W)\{(V+W)(V-W) + 4\Psi(\Psi - V)\} \equiv \alpha_P.$$

The expression of the profit maximizing reservation screening level of a hierarchy is

$$S^H = \Psi + k(\alpha, V, W).$$

This is an interior solution when

$$-2\Psi + V < k(\alpha, V, W) < -W.$$

The comparative statics result of this interior solution regarding α is the same as for a polyarchy, i.e. a better portfolio will result in a higher acceptance probability of local bureaus in a hierarchy. The boundary solution Ψ - W generates expected profits of

$$\alpha V(V+W)^2/4\Psi^2. \tag{4}$$

This boundary solution will emerge when there is not an interior solution and

$$(2) \leq (4)$$

$$\Leftrightarrow \alpha \leq W(2\Psi - V - W)^2/(V+W)(4\Psi(\Psi - W) + (W+V)(W-V)) \equiv \alpha_H.$$

It can be shown that $\alpha_H < \alpha_P$.

Suppose that $\Psi - W < S^i < \Psi + V$. The profit maximizing reservation screening level of a polyarchy is Ψ - W and the associated profits are given by (3). It is easy to show that there is no screening level in the above range which exceeds the profits given by expression (4), because any realisation of y larger than Ψ - W has to be a good project. Similar observations hold for a hierarchy. The profit maximizing reservation screening level of a hierarchy is Ψ - W and the associated profits are given by (4).

Suppose that $\Psi + V < S^i$. There is no project which can generate revenues exceeding an S^i satisfying this inequality. All projects will be rejected and the expected profits for both architectures are therefore zero.

The value of α for which the profit maximizing screening level is a boundary solution and switches from Ψ - W to -Ψ + V is defined as α_H for a hierarchy and α_P for a polyarchy. These parameters are only relevant when α is such that there is a boundary solution. Figure 7 summarizes these results when there is not an interior solution for the hierarchy as well as the polyarchy.

The range of α for which the profit maximizing screening level is an interior solution will now be determined. This range is $[\alpha_l^H, \alpha_u^H]$ for the hierarchy and $[\alpha_l^P, \alpha_u^P]$ for a polyarchy. Figure 7 illustrates the relationship between the range of α for which there is an interior solution of either a hierarchy or polyarchy and $k(\alpha,V,W)$.

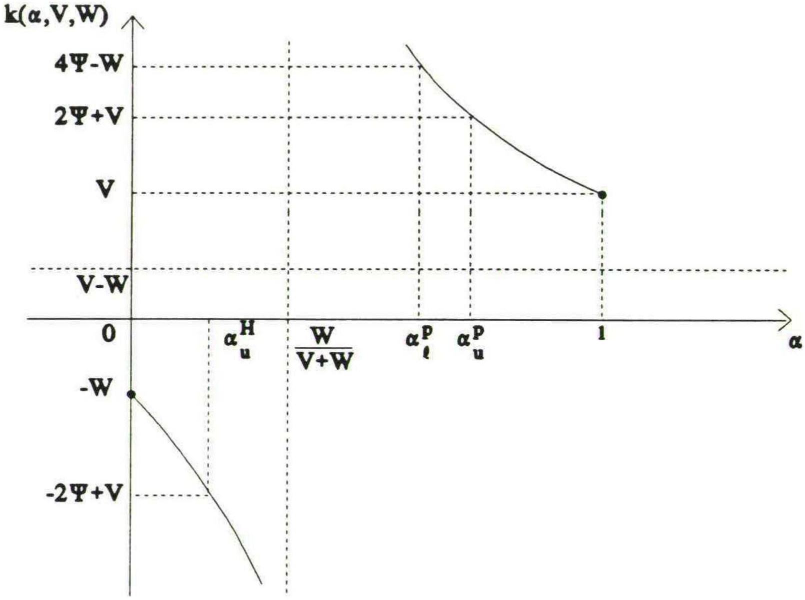

Figure 7: Portfolio composition and interior solution range.

We get after some rearranging that

$$\alpha_\ell^H = 0$$

$$\alpha_u^H = \frac{W(V+W-2\Psi)}{(V+W)(W-2\Psi)}$$

$$\alpha_\ell^P = \frac{4\Psi W}{(V+W)(4\Psi-V)}$$

$$\alpha_u^P = \frac{W(2\Psi+V+W)}{(V+W)(2\Psi+W)}.$$

The expressions for α_u^H, α_ℓ^P, α_u^P, are all a decreasing function of V. It can be shown that the relationship between α_H and α_p and these ranges for which there is an interior solution results in

$$\alpha_H < \alpha_\ell^P$$

$$\alpha_u^P < \alpha_p.$$

Figure 8 summarizes the results regarding the profit maximizing screening level choice and the portfolio composition, where α_H is assumed to be larger than α_u^H. (If $\alpha_H \leq \alpha_u^H$, then the interval $[\alpha_u^H, \alpha_H]$ disappears from figure 8.) Notice that it follows immediately from figure 8 that the profit maximizing screening level choice of bureaus in a polyarchy is at least as high in a hierarchy.

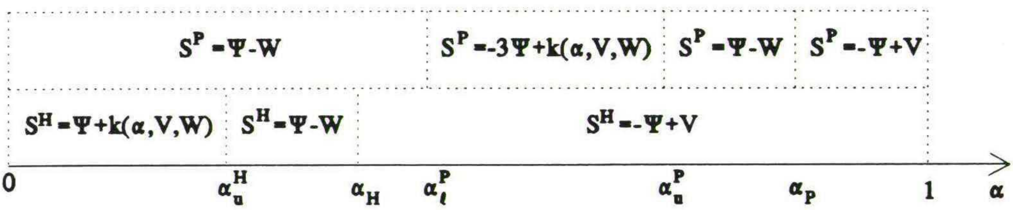

Figure 8: Profit maximizing screening level and portfolio composition

The profit maximizing screening level of a bureau in a duopoly is similar to the monopoly situation. The expression for $p(x,S^i)$ does not change, but expected profits of architecture i when faced with architecture j are now equal to $\alpha f_i(1-f_j/2)V - (1-\alpha)f_iW$. If there is an interior solution when $-\Psi + V < S^i < \Psi - W$, then the expression of the profit maximizing screening level choice is

$$S^{Pj} = -3\Psi + k(\alpha,V,W,f_j)$$

and

$$k(\alpha,V,W,f_j) = \frac{\alpha(1-f_j/2)V^2 + (1-\alpha)W^2}{\alpha(1-f_j/2)V - (1-\alpha)W}$$

for a polyarchy facing architecture j and

$$S^{Hj} = \Psi + k(\alpha,V,W,f_j)$$

for a hierarchy facing architecture j.

The derivative of $k(\alpha,V,W,f_j)$ with respect to f_j is positive. Screening levels are inversely related to f_j, which implies that there is a negative relationship between the profit maximizing screening level of the firm (having either a hierarchy or a polyarchy) and the screening level of the rival. Screening levels are therefore strategic substitutes.

The comparative statics results of the equilibrium screening level choice when both firms have the same architecture can be obtained by using the formulas of Cardano for third degree polynomials. They are cumbersome and do not provide much insight. Recourse has therefore been taken to a graphical illustration, which is generated by the computer package 'Mathematica'. Figure 9 shows the comparative statics results regarding α and V for $W = 6$ and $\Psi = 10$ and both firms having a polyarchy. They resemble the monopoly situation in that the profit maximizing screening level choice increases when α and/or V decreases.

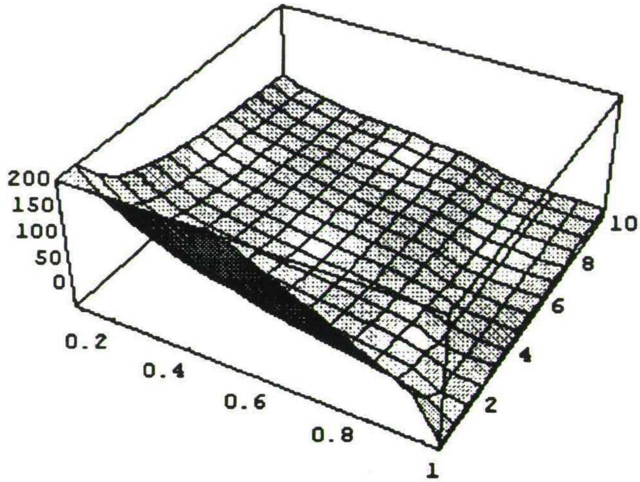

Figure 9: Comparative statics results regarding α and V

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